LCA for Ocean Energy

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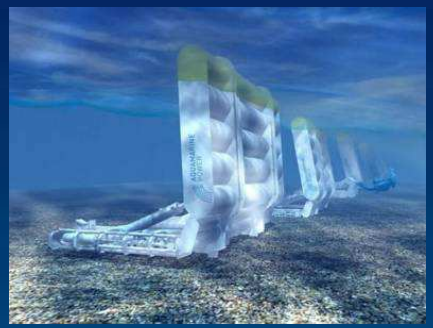

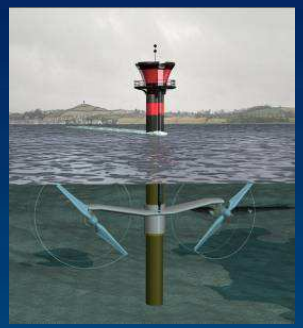

Images from www.pelamiswave.com, www.aquamarinepower.com, www.marineturbines.com and Erik Friis-Madsen at en.wikipedia

Introduction

- The *process* of converting “clean” ocean energy into electrical power has an environmental impact
- Pollutants are emitted during the manufacture, operation & decommissioning of generators
- LCA quantifies such environmental impacts, to:
  - Inform design developments
  - Demonstrate benefits over other technologies

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Images from www.picturesdepot.com and info.industry.siemens.com.

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Introduction

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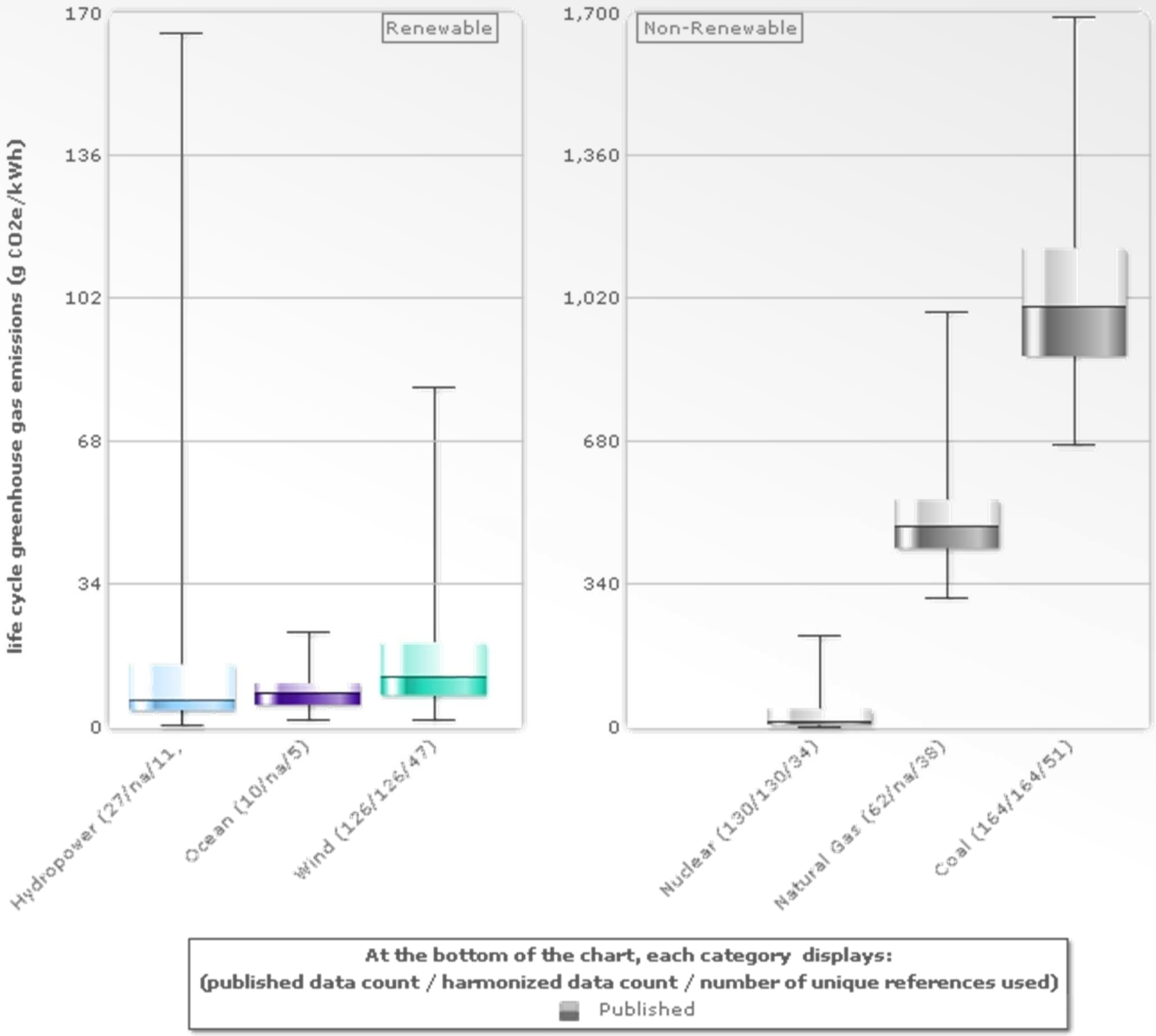
Global Warming Potential



Data from NREL Harmonization Project, http://en.openei.org/apps/LCA/

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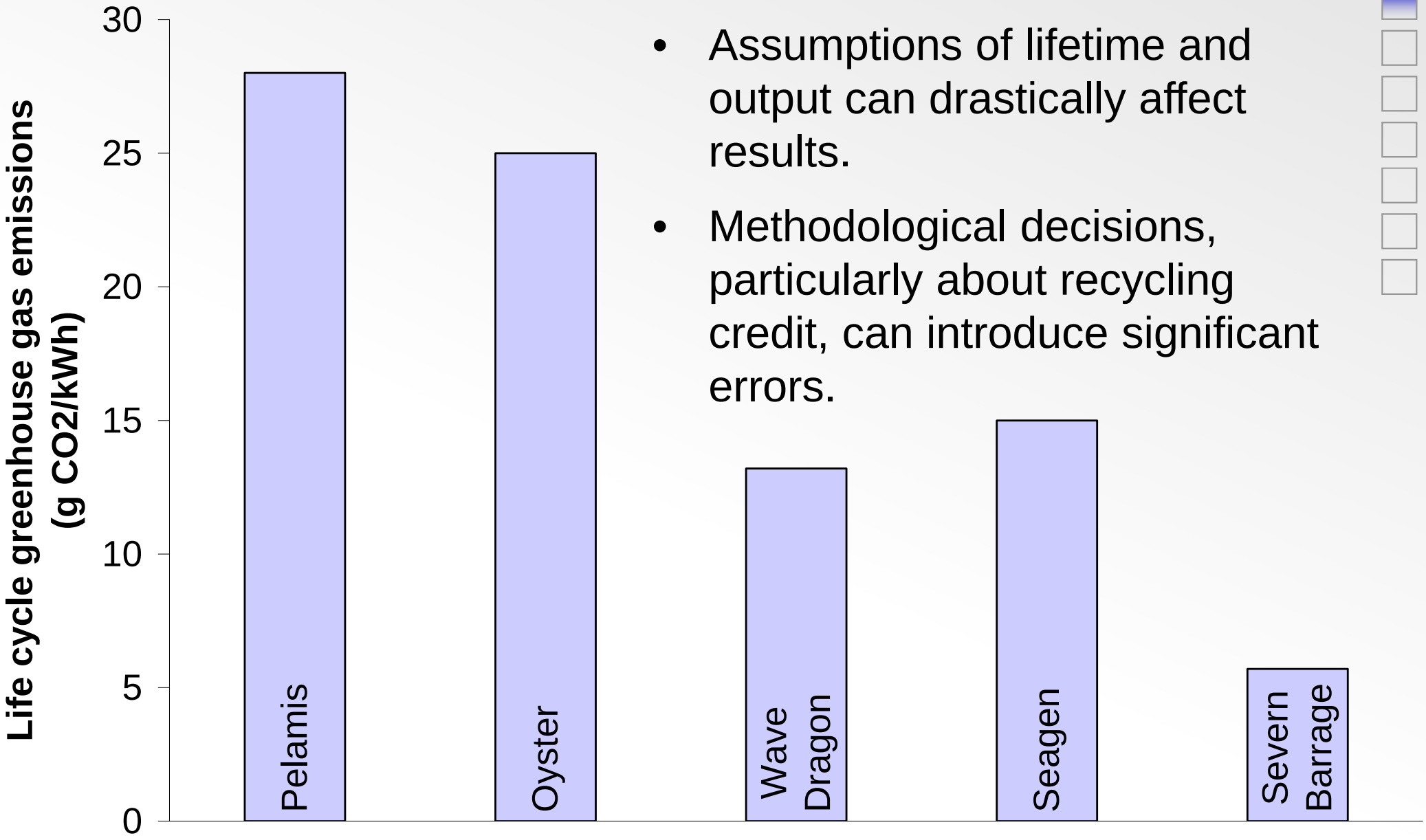
Carbon Emissions



- Assumptions of lifetime and output can drastically affect results.
- Methodological decisions, particularly about recycling credit, can introduce significant errors.

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Thomson *et al*, 2011; Walker and Howell, 2011; Sorensen, 2008; Douglas *et al*, 2008; Woollcombe-Adams, 2008

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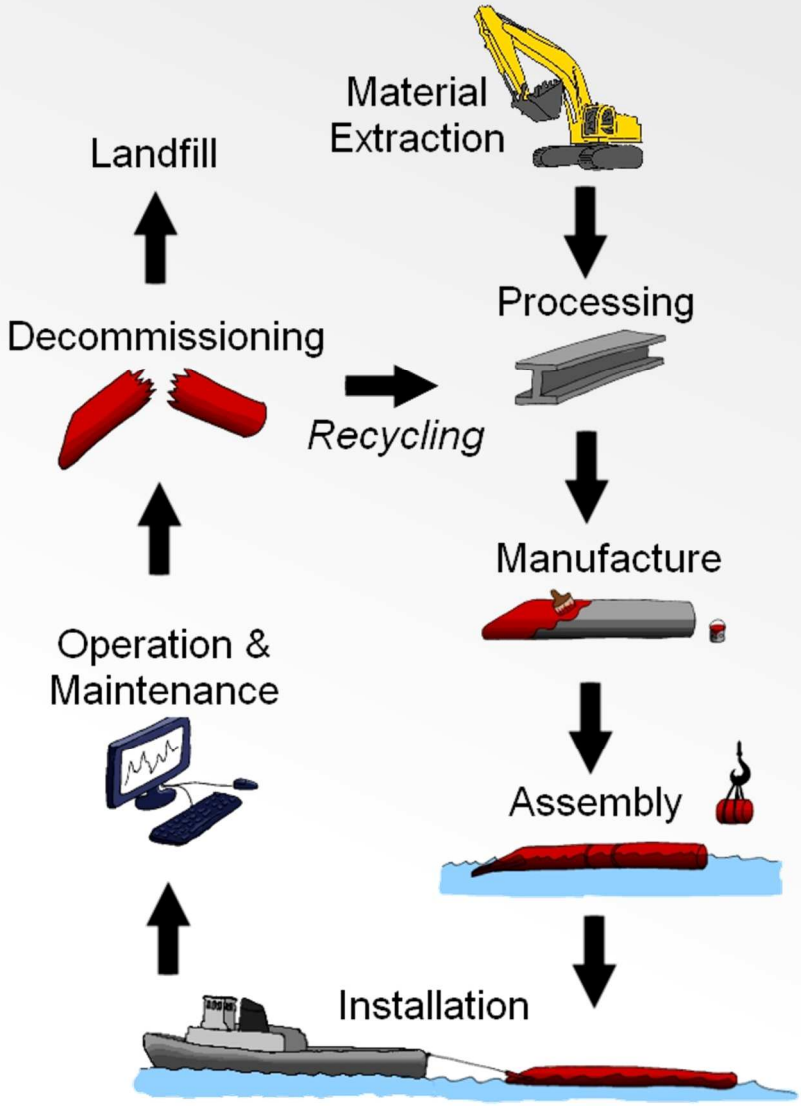
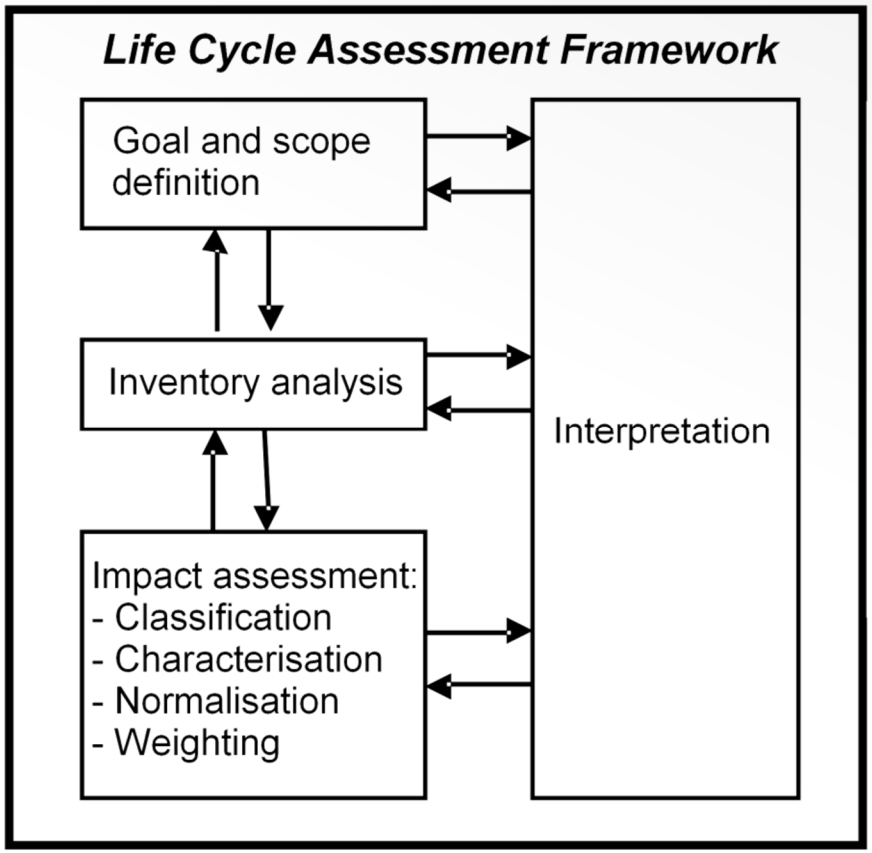
Life Cycle Assessment

- Often used to certify environmental credentials
- Governed by ISO 14040 series of standards.
- Systematic analysis of resource use and pollutant emissions at each life cycle stage
- Results presented as environmental impact potentials
- Analysis of sensitivity to assumptions is essential



Life Cycle Assessment

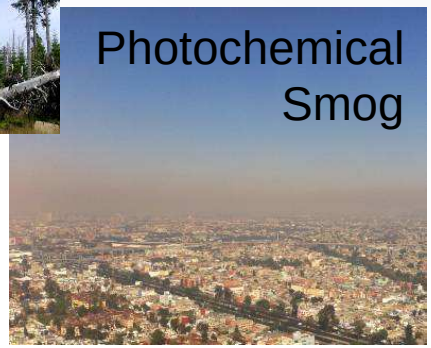


Human Health

Stratospheric ozone depletion

Aquatic & terrestrial toxicity

Resource Depletion



Land Use (Waste)

Cumulative Energy Demand

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Images courtesy of www.jabulela.com, ArtMechanic, F Lamiot, Fidel Gonzalez

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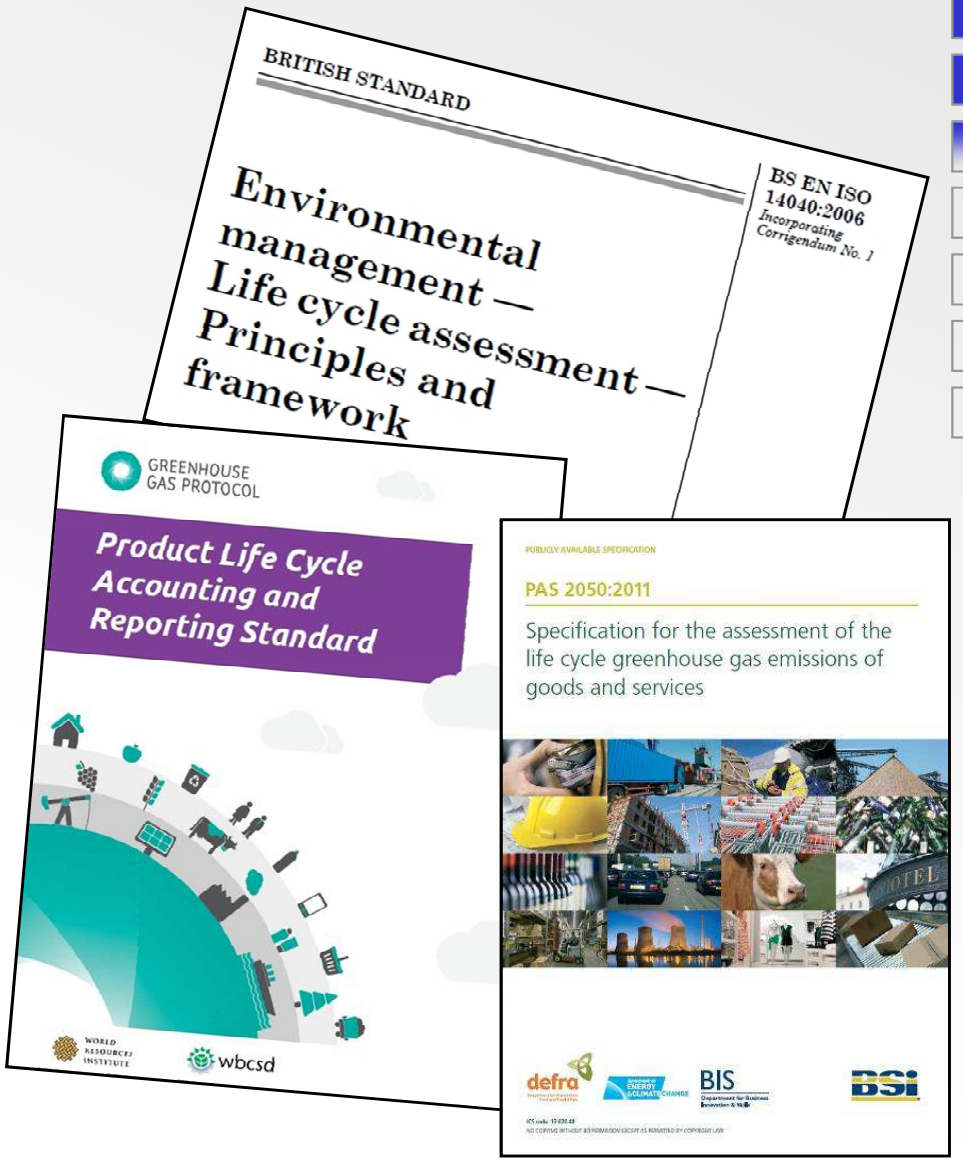
Guides and Standards

- Greenhouse Gas Protocol and PAS 2050 also provide good practice guidance for LCA
- Functional unit: 1 kWh output energy
- Whole life cycle: Materials/manufacture and shipping likely to have greatest impacts
- System boundary: Point of connection with the grid



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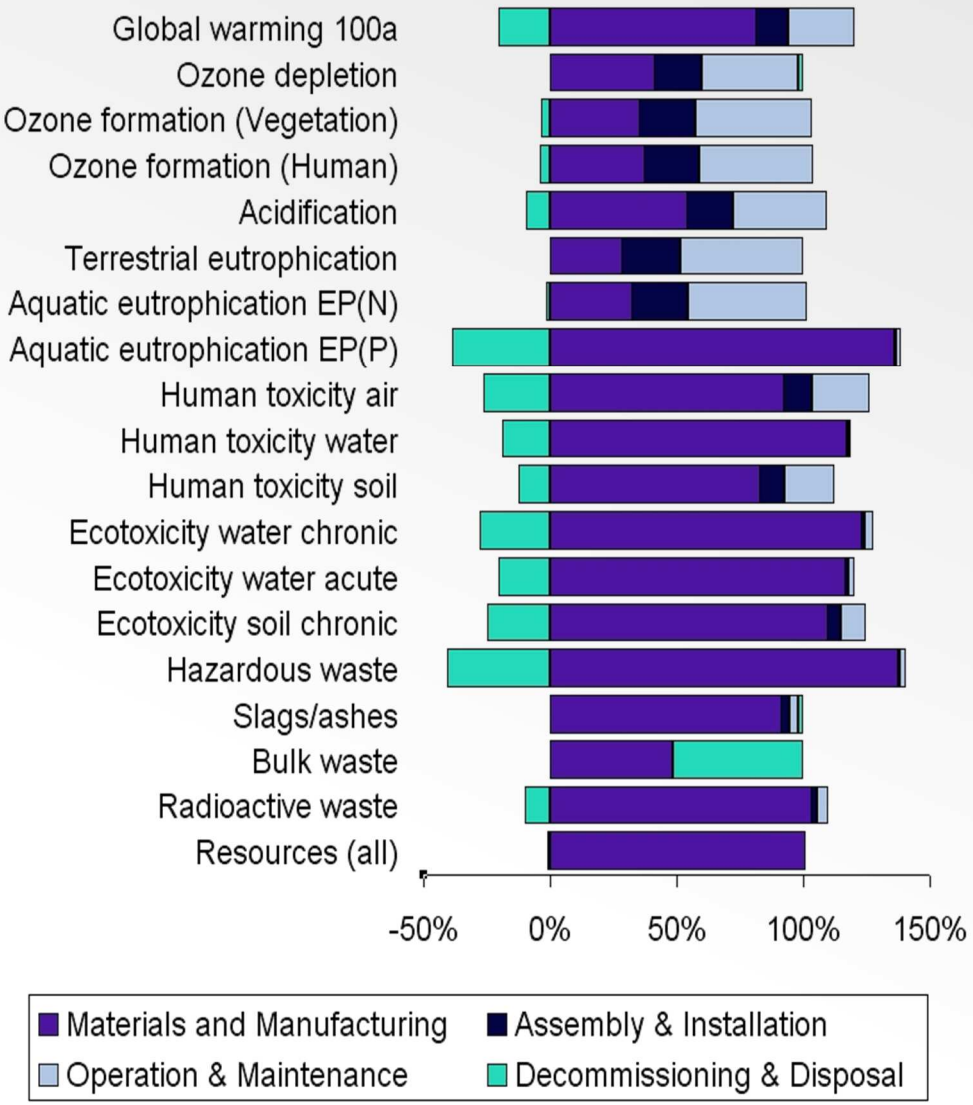
Full LCA of the Pelamis P1

- Greatest impacts from manufacturing and maintenance stages
  - Steel production
  - Sea vessel operations
- Energy intensity
  - 411 kJ/kWh
  - 27 months payback
- Global warming potential
  - 27 gCO_2e/kWh
  - 13 months payback



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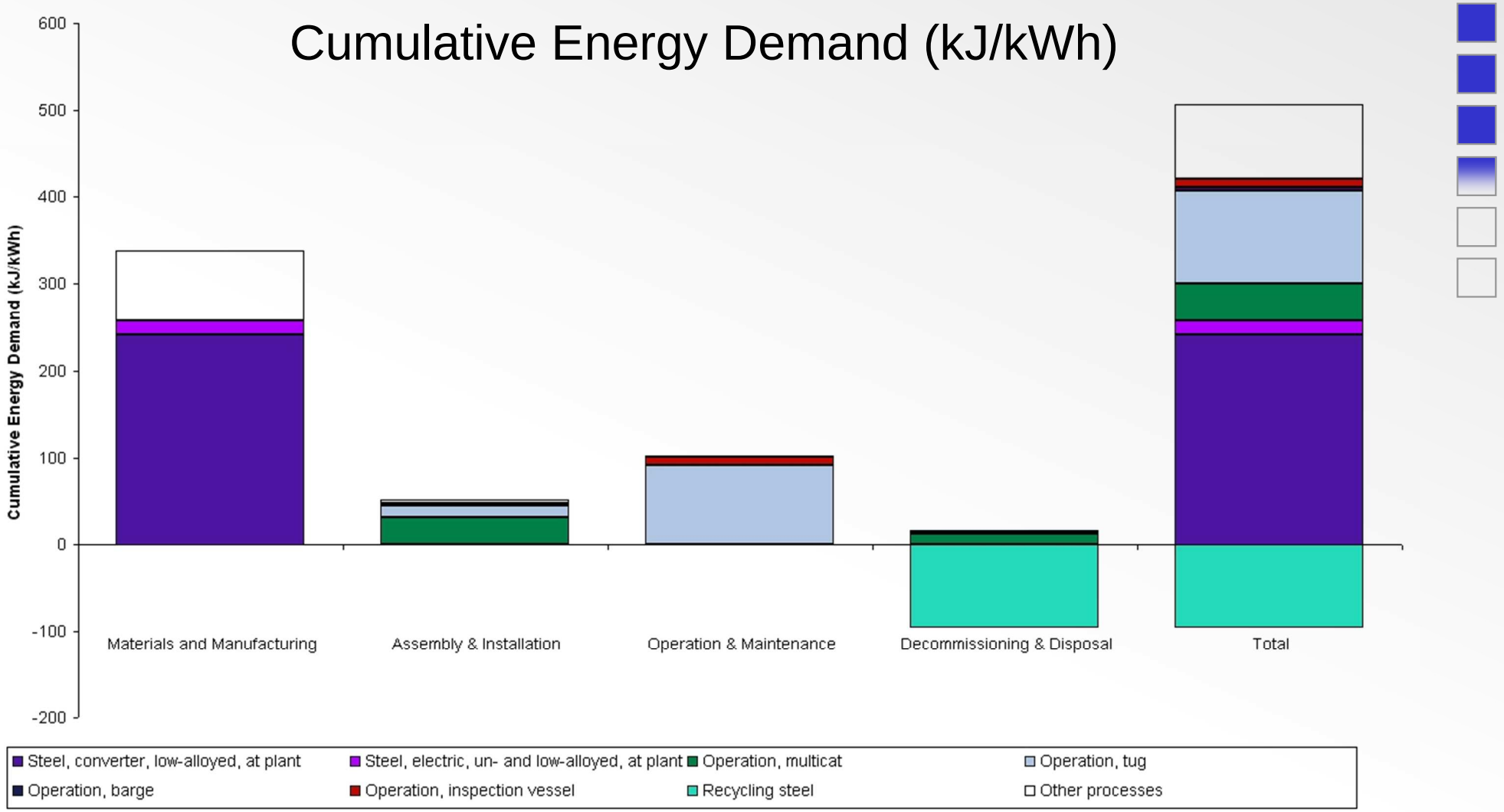
Potential Improvement



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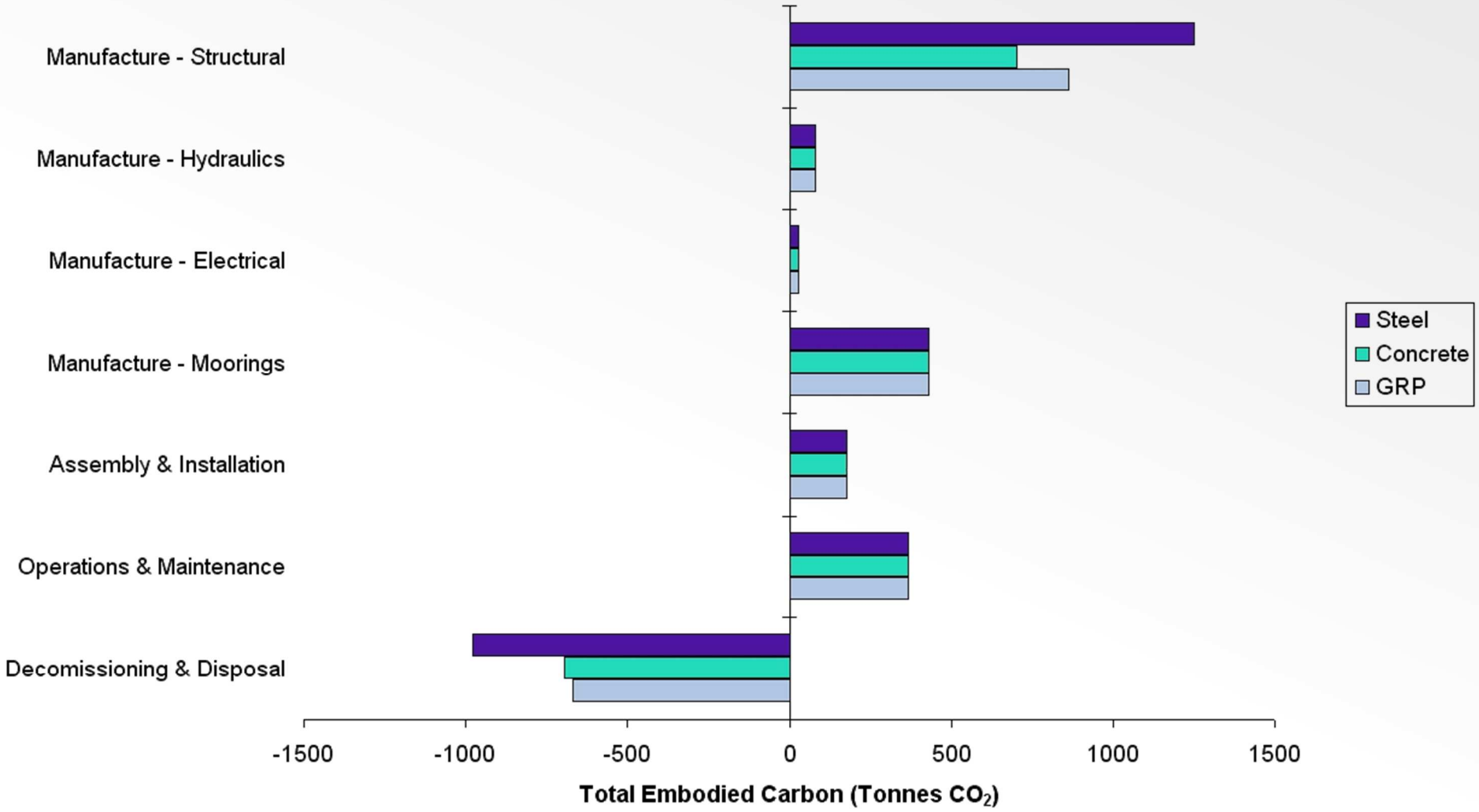
Alternative Materials



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Data taken from Parker R.P.M., Harrison G.P., Chick J.P. (2007): Energy and carbon audit of an offshore wave energy converter. Proc. IMechE Part A: J. Power and Energy, 221(A8), pp. 1119-1130

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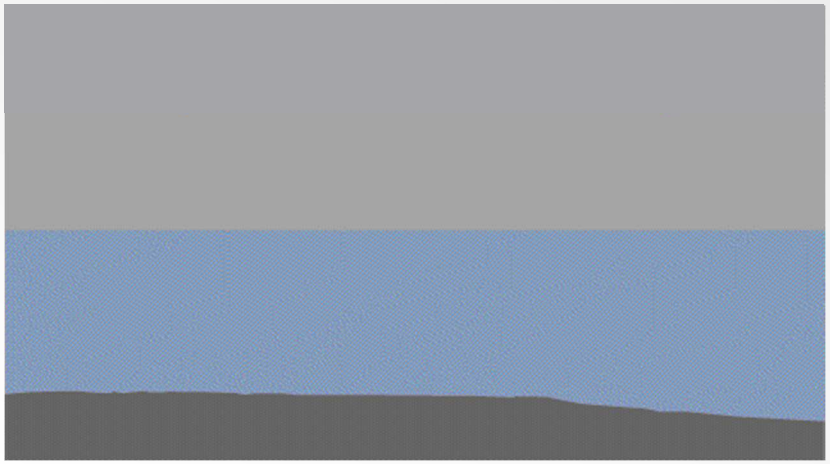
Conclusions



- LCA is used to certify environmental credentials and it forms the basis of all carbon footprinting tools.
- The use of LCA throughout product development can inform design decisions.
- Life cycle environmental impacts of ocean energy are poorly understood in comparison to other renewables.
- Manufacturers are best placed to carry out/commission LCA, as they have access to primary data.

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Graphic adapted from www.pelamiswave.com.

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Recycling Methods

- Recycling provides an environmental credit
- No consensus on allocation methodology:
  - Product that **uses** the recycled material (Recycled Content method)
  - Product that **produces** recyclable scrap (Substitution method)
  - **Both** products (50:50 method)
- The recycled content approach is most often applied
- Parker *et al.* applied the substitution method, as recommended by the IISI

Image courtesy of Pelamis Wave Power Ltd.

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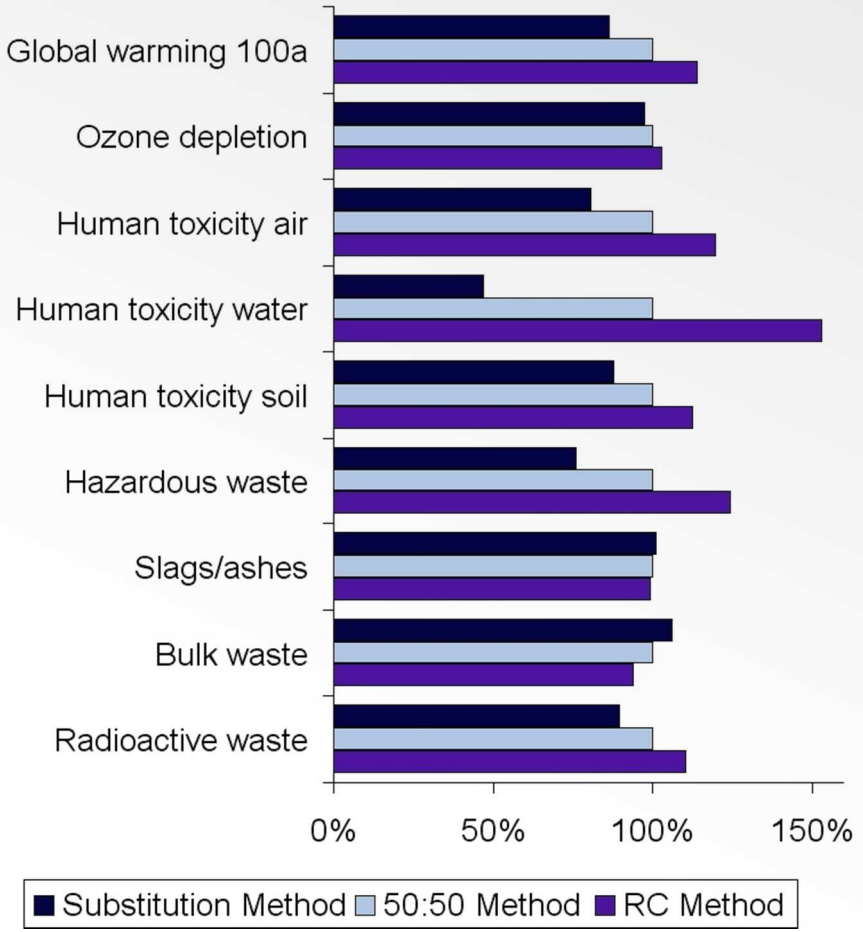
Recycling Methods

- Most results vary by about ± 15 % with the substitution method providing lowest result.
- Human toxicity water varies the most (± 50 %).
- Inclusion of recycling processes results in an increase in waste for the substitution method.
- GWP: 27 ±4 gCO_2e/kWh
- Energy: 357 ±47 kJ/kWh



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